GEOTHERMAL DRILLING IN CERRO PRIETO

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ABSTRACT

To date, 71 geothermal wells have been drilled in Cerro Prieto. The activity has been divided into several stages, and, in each stage, attempts have been made to correct deficiencies that were gradually detected. Some of these problems have been solved; others, such as those pertaining to well casing, cement, and cementing jobs, have persisted.

The procedures for well completion--the most important aspect for the success of a well--that were based on conventional oil well criteria have been improved to meet the conditions of the geothermal reservoir.

Several technical aspects that have improved should be further optimized, even though the resolutions are considered to be reasonably satisfactory.

Particular attention has been given to the development of a high-temperature drilling fluid capable of being used in drilling through lost circulation zones. Conventional oil well drilling techniques have been used except where hole-sloughing is a problem. Sulfonate lignitic mud systems have been used with good results. When temperatures exceed 300°C (572°F), it has been necessary to use an organic polymer to stabilize the mud properties.

DISCLAIMER

The development of drilling in Cerro Prieto, has undergone different modifications that can be resumed in five principal stages, as it is shown in table 1. This table shows the dates and specifications of the casings that were used to drill wells according to the profiles shown in Figure 1. The changes took place slowly and were caused by two factors, mechanical failures of casing due to tensional and compressional stresses, and excessive scaling.

One of the first modifications was that round threads were changed to Buttress and these with time changed to Hydril SEU. Weight and quality of steels were also modified. Grades K-55, N-80 and L-80 have been tested and actually grade C-75 is being used. Severe interior and exterior problems were detected as well as embrittlement of casing. A conflict has emerged from the fact that the greater the capacity of steels to withstand stresses, the greater sensibility to the hydrosulphuric action, and corrosion damages have been more notorious through time.

Another variation has been in the design and arrangement of production casings, using in some cases hanging liners and in others directly slotting the casing. This alternative was used from 1976 to 1978, and we consider it most satisfactory. Since 1964 only hanging liners were used, but a rapid increase in scaling with the change in diameters, was noted at the top of the liner. A two stage cementing job was done to perform this type of completion. The first stage was short, of 100 m. length, the second was definite up to the surface. This method proved to be safe and was under control up to 1700 m. deep. As wells were built deeper in Cerro Prieto, it was not possible to control two stage cementing jobs, as circulation losses were easily originated by the weight of the slurry, and it was decided to return to the method of completing a well with a hanging liner. Besides, thermal conditions below 2000 m. have been higher than in other wells, and making a proper selection of the producing stratum eliminated the problem of scaling.

The mechanical damages caused by tensional and compressional stresses that in the first wells were of 100%, were reduced to the minimum, with a good constructive operation, cementing jobs, using cements modified with perlite and silica flour, following besides and adequate method to heat and develop these wells. Up to date corrosion is the most serious problem not resolved, especially in the outside of casings that sometimes makes a loss of 100%.

STRATIGRAPHIC COLUMN

The stratigraphic and lithologic characteristics prevailing in the Cerro Prieto geothermal field influence greatly the drilling and completion of wells, that in our case correspond to sedimentary rocks and a water dominant reservoir. This fact makes Cerro Prieto different form other geothermal fields in the world that have igneus rocks and vapor dominant reservoirs.

In our case, formations are alluvial, plastic-sandy clays that consolidate with depth and by thermal metamorphism. Three principal bodies can be distinguished, the shallower is soft and plastic, the second body is more consolidated and transitional, and the lower is made up of alternating sandstones and shales,and it is here that hot water is stored. Figure 2 shows with certain detail a general strat igraphic column that with a little variation in thickness in each of the principal bodies, may be applied to all the Cerro Prieto area. Another important factor to be considered, is the effect of tectonism in this zone that is clearly indicated by the presence of fracturing and loose sections in consolidated shale bodies, that sometimes result of greater size than would correspond to the cut of the bit used. This situation caused cave-ins in some of our wells, as in well M-92. A certain reaction to thermal shock make this situation worst, when hot formations are penetrated.

DRILLING

We will refer to those drilling aspects that have particular characteristics in geothermal wells. In our case, the tools have been common, formed by 4 1/2" Ø D.pipe and drill collars. In some wells, we intended to use stabilized tools but penetration rates decreased and deviations were encountered, this atributed to the increase of viscosity in muds, by the contamination of geothermal fluids. Bits used were conventional of different types and brands, to drill alternated sandstones and shales, with hot water content, but they wore out and rendered slow penetration rates, calibration diameter loss and loose fragments frequently caused "fishing"problems. Drill bit failure is a major problem in drilling high temperature geothermal wells, a new type of bit to withstand this factor, is being sought.

In our case, it is important to indicate that Hydraulics should contemplate that some of the diameters in a drilling program are relatively higher than those used in drilling oil wells, requiring only one pumping equipment to keep the mud circulating in the annular spaces at 120 ft/min. Other special equipment is the cooling tower to cool circulating mud and the equipment for the disposal of fluids. The cooling tower should be designed to decrease the temper ature in and out of the well, in at least 20°C. We think that increasing the cooling tower capacity will bring about a saving in chemical additives, and problems in penetrating very hot zones.

Besides these equipment, the application of some other sophisticated equipment, is fundamental, to effectively eliminate fluids. In our case, sand or clay eliminators were not enough and more complete systems had to be used with very good results.

The use of preventors with rubber seals to withstand high temper ature geothermal drilling, has lead to a particular design that permits the cooling of rams, making the use of this equipment safer.

As we already mentioned, the rest of methods and systems are those common to oil well drilling.

DRILLING MUD

After using different types of muds, actually a sulfonate lignitic mud with a bentonitic base, is being used, additives for high temperatures found in the hot zones drilled, are being added. The program shown in Table 3 worked satisfactorily for 1700 m. depths, but as depths grew larger and temperatures increased above 275°C., it was necessary to use an organic polymer when penetrating the hotter zones, to control the characteristics of mud. In the same table, characteristics of mud and additives recommended, are shown , so that during drilling the best control of mud is achieved.

Also in Table 3, the type of equipment for fluid disposal and temperature control for the cooling tower, are indicated.

The most serious problem encountered has been circulation losses, in some cases induced and in others caused by the weakening of the penetrated zones and the presence of possible faults and fractures. These problems have been solved by using simple materials for circulation losses, nevertheless, the use of calcium chloride and sodium silicate, when pumped during drilling, have proved to be satisfactory up to date in the case of severe losses, the best solution , has been the use of cement plugs that after an 8 or 12 hour setting, are perforated to continue drilling.

CEMENTS AND CEMENTING

The cements used in Cerro Prieto, have been type H or G, A.P.I., modified, with 40% silica flour and perlite or activated pozzolan. The amount of perlite or pozzolan has been modified however, in the present a sack or a sack and a half is mixed to a sack of cement. We recall that the objectives of cementing are to seal or cement the first 200 or 300 m. above the reservoir, and from there, to the surface, pack and support the casing, but at the same time, to permit an axial expansion of the same. A greater proportion of silica flour and perlite, reduces the cement bond to the casing, this is desirable to permit the elimination of circulation mud or water pockets, that could have been caught, besides the axial expansion.

Cementing in geothermal wells, is planned to cement all casings from the bottom to the surface. Table 4. When drilling 2000 m. or over, hydraulic charges are almost impossible to control, without originating a circulation loss that could cause invasion of the producing zones, or at least defficiencies in cementing jobs, that in some cases is the total lack of cement. Mechanical failures of the accessories used to cement in two or more stages, are associated to this aspect. Up to date, these elements have not been able to function properly. Together, they create one of the most difficult and inconvenient aspects in modern drilling. Lighter cements are being tested to reduce the problem we have mentioned, and also, improved cementing collars are being sought, to tolerate geothermal conditions and function adequately. Table 4.

OTHER PROBLEMS

Some other problems in Cerro Prieto are, water packing due to a defficient hydraulic system, stuck-ins caused by differential pressure of the neighboring zone, and discrepancies in the columns due to thermal effects, cave-ins closely related to aspects of Tectonism because of faults and fractures detected in this zone, and when hot lutitic bodies are penetrated a certain thermal shock makes the problem more severe. The best solution when this cave-ins are excessive, is to rapidly recement and clean the cement.

Finally, "fishing" is also a very serious problem when it occurs in the hot zones, since the equipment frequently used in this type of operation is damaged by high temperatures, being impossible to make the operation, if the "fish" is not cooled efficiently. This is an example of the improvement that is needed in the equipment and tools. Only 10% of this type of jobs have been successful.

MEXICALI VALLEY

The Mexicali valley is located in the North part of the state of Baja California, forming part of the Colorado River Delta, which is constituted by the Mexicali, Imperial and Yuma Valleys, the latter in the U.S. Figure2., and the Cerro Prieto Geothermal Field is located 30 km. Southeast of Mexicali, Baja California, Figure 3, in this place the Cerro Prieto volcano is found.

BUILT WELLS

To date, 83 wells have been drilled, of exploratory and producing type, for a total of more than 155,000 linear meters. The great part of these wells, is found in Block I, Figure 4. The field has been divided into three blocks which are indicated in this same figure characterized by the depth of the producing layers. The first block is located West of the Railroad tracks, where the first group of wells was drilled, to feed Turbines 1, 2, 3, and 4. This area called Cerro Prieto I, is made up by wells of two reservoir depths, the first at 1300 m., and the second in the South, close to 2000 m. In block II the reservoir is found at 2700 to 3000 m., in Cerro Prieto III from 2300 to 2700 m. Undoubtedly, Cerro Prieto II block has the higher hydrothermal content reservoir, since the evaluation of wells built in this area reports up to 300 tonn/hr. of steam and 200 t/hr. of separated water. The first wells drilled in 1964, in the first stage of Cerro Prieto I, made only 60 tonn/hr. of steam. In the area of Cerro Prieto III, some wells have produced 200 tonn/hr. of steam, and the program contemplates drilling in this area, and some other wells in the area of Cerro Prieto I, as it is shown in Figure 5. Of the different wells built in the stages mentioned, we will now comment the characteristics of some of them, emphasizing the thermal influence and the problems encountered during drilling.

We have considered very interesting to make a summary of certain aspects related to the construction characteristics of geothermal wells and their design, circulation losses, difficulties to obtain electric logs with conventional tools, and thermal logs which are fundamental in this type of wells to detect the producing zones. The application of cements and the difficulties during the cementing operation, the elements that properly correlated will permit the solution of the zones with higher thermal energy to be defined, and finally the previous stage, which requires a series of events to carry the well to production to evaluate its energetic capacity. Table 5.

In a great measure, the thermal factor is the cause of all the aspects mentioned above. It is evident that wells exist in areas with igneous rocks, vapor dominant, different to those found in Cerro Prieto, and this makes us think that geologic conditions, geochemical content, type of fluids, etc., make the search of a technology more complex, to build this particular type of well. The completion aspects of Cerro Prieto Geothermal wells, are presented in a separate companion paper.[1]

WELL M-8

This well was built in the months of June and July, 1966, in the North part of Cerro Prieto I, close to the boundary of the South part. Figure 6. The design was very simple, using a conductor, a surface casing, and intermediate 11 3/4" Ø casing, Buttress threads, to a depth of more or less 1000 m., and a suspended liner that reached 1300 m. In this particular case, the tree was anchored in the 11 3/4" Ø casing, through a threaded well head. This situation favored the unfastening of the tree and loss of control in this well. Figure 6 shows the casing profile used in this well, also the three principal lithologic bodies are shown, as well as correlated temperatures of each of them, and the penetration plot when drilling this well. It is important to note that through a series of plots of this well and others, the problems of drilling hotter zones, greatly increase drilling times and costs.

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[1]"Geothermal Well Completion in Cerro Prieto"
B. Dominguez & Juan M. Cobo, C.F.E.
International Conference
Geothermal Drilling Completion Technology
Albuquerque, New Mexico

In this case, the 20" Ø as well as 15" Ø drillings were normal, since formations and temperatures were also normal, nevertheless, logs installing and cementing the casing, absorbed 16% of total drilling time. The drilling of the 15" hole for the 11 3/4" Ø casing reported 37% of the time used, covering almost 1000 meters, but drilling the last 200 m. of the producing zone, with a 10 5/8" Ø hole, took 21% of the total time, and logging and the installation of the liner absorbed 9%. The drilling of this well took 30 days, of which a great percentage was used in penetrating the hot shales with temperatures between 180°and 218°C.

This well was completed with a 7 5/8" Ø liner, and from the results of the analysis of its mineralogic contents and cements, we can think that the hot reservoir was partially penetrated. Drilling of the last 200 m. was slower than the other stages, since it took 21% of the total time. We had no difficulties in installing the liner and running log.

After the completion of this well and during the evaluation stage, a loss of control occured when the christmas tree unfastened with the anchoring well head from the 11 3/4" Ø casing. The well head was threaded and the geothermal fluid vibrations caused this accident. To date, in Cerro Prieto, well heads are welded.

WELL M-21A

This well was built in 1974, Figure 7, a 7 5/8" Ø production casing was designed from the bottom to the surface, a depth of 1300 m. was reached, and it is located in the Block Cerro Prieto I. In this well, the transition zone in the lithologic column was very short, predominating the zone with a temperature of 210°C., a little less than the one encountered in well M-8. Drilling was slower than in the previous well mentioned, totally 55 days. Logs, installation of casing and cementing jobs, inside the intermediate and production casing, were normal, and the time used was adequate. Eventhough, this well has proved to be a good producer, and we observe that the correlation between the effect of metamorphism of the transition zone the colder zones, in the reservoir temperature, will render high or low energetic results in the future.

WELL M-150

In 1978, 90 days were used to drill this well reaching a depth of more than 2100 m. Figure 8., it is located in the Area of Cerro Prieto III. The depth of this well caused excessive circulation losses, and the design included an intermediate 9 5/8" Ø casing up to the top of the reservoir, where it was necessary to plug with slurry to guarantee the installation and cementing of the casing. The lithologic column in this case, represented a powerful transitional zone and a partial penetration of the reservoir, maximum temperature reached was 190°C., and the temperature of the ------ reservoir up to 280°C.

Drilling of the first part up to the end of the transition zone was reasonable and without problems, with a normal penetration rate, -- as well as the installation of the 13 3/8" Ø casing which reached 1000 m., however, drilling and the problems encountered from the end of the transition zone to penetrate the reservoir, absorbed more than 50% of the total drilling time used in this well. Drilling of the last 200 m. to penetrate the reservoir, with an 8 1/2" Ø bit, was normal, as well as the operation to hang the liner. This well is cited as an example, because the high temperatures encountered greatly increased the drilling time.

WELL M-169

This well was built in 1979, requiring 90 days for its construction, reaching a depth of 2300 m. Figure 9. In this case, the original design intended to reach more or less 2000 m. with an intermediate casing, hang a liner and penetrate the hot zones, considering cave-ins and circulation losses.

The lithologic column of this well, shows a powerful transition zone with temperatures up to 160°C., and the reservoir with a maximum temperature of 245°C. Drilling and installation of surface casing was normal and satisfactory, up to the boundary between the transition zone and the zone of the reservoir, since in this area and before installing the 9 5/8" Ø casing, excessive cave-ins occurred and circulation losses, and 25 days were needed to re-establish the zone and install the casing, which made up 31% of the total drilling time of this well. Finally, the casing could be installed up to 1600 m. only, it was cemented and continued drilling up to 2400 m., with an 8 1/2" Ø bit, where cave-ins and circulation losses were again encountered, with an increase in the drilling time, that at this stage made up 20% of the total time. It was necessary to seal off the stratum, and to cement the 7" Ø liner that was suspended from the production casing, a long operation that absorbed almost 18% of the time. This well is also an example of the fact that penetrating hot deep zones and problems encountered, exaggerate drilling time, but as in the previous well, the production results of this well have been very satisfactory.

WELL M-120

This well was built in 1979, and is located in the area of Cerro Prieto III, with a total depth of 2100 m. Figure 10, the lithologic colum of this well presents an important transition zone with a temperature of 150°C., and the reservoir with a maximum temperature of 274°C. Drilling to install the 9 5/8" Ø as well as the cementing operations. It was intended to leave this casing at the start of the reservoir which penetrated with an 8 1/2" Ø bit, from 1600 a 2100 m. This stage of drilling required more time than normal, the characteristics of the temperature found in the reservoir made penetration slow. Finally, a 7" Ø liner was suspended and cemented to seal the less useful and less important part, which was contaminated with calcium, and left open to production the last 200 m. This was a normal operation. Here, an excessive drilling time was required to penetrate the hot zone of the reservoir, making up 19% of the total drilling time for this well, which was 70 days. In general terms, the construction of this well was normal.

Here, we have presented some contrasting examples to emphasize the problems encountered when drilling the transition zone, and above all, the reservoir. Two possible alternatives to solve these problems, would be, to penetrate partially the reservoir for its exploitation, and the other is to completely cross it to select the most favorable zone for exploitation. This last alternative offers the risk of circulation losses, cave-ins and difficulties during cementing operations, with a consequent increase in drilling time and costs, and possible constructive defficiencies, that in the future could cause cement degradation or corrosion damages in the casings. It is evident that more problems are associated with higher temperatures found in the reservoirs.

WELL COMPLETIONS

The completion stage in which all the jobs and operations that help to penetrate the reservoir and achieve the exploitation of the same, is based in the results of the analysis of temperature logs, electric logs, lithologic conditions, cements and mineral content. These parameters serve as guides to judge the penetration when drilling the reservoir before suspending it, to consider reaching the objective to obtain a satisfactory energetic recuperation.

CONCLUSIONS AND RECOMMENDATIONS

Undoubtedly, there exist particular problems in drilling geothermal wells, and several of these have been experienced in the geothermal field of Cerro Prieto. Some solutions that we consider reasonably operating, have been tried, however, further work is necessary to improve these solutions and find others to be applied adequately. Table 6.

The mud program followed in the present, should be optimized to reduce its costs, improving the capacity of the cooling tower, and to decrease the percentage of chemical additives required in the different events of drilling. Drill bit failure is a major problem, especially when they are used to penetrate the reservoir, and other types should be applied that would render an economic advantage increase penetration rates. No damages have been noted in the string, out of the ordinary in this type of job. Cementing operations have not always been controllable and probably, a solution would be to use light cements, that would tolerate degradation through time, since the improvement of cementing collars is apparently more difficult.

Studies have been carried out to treat cave-ins with chemical reactives, but specialists suggest that the problem is mechanical, not chemical. A grinding of lutitic bodies favors this cave-ins and the effect of thermal shocks accelerates them. A slow and expensive solution is rapidly recementing and cleaning this cement. One of the most difficult problems to be controlled is when "fishing" has to be done in the reservoir. Systems and tools should be improved to make this operation successful, up to date results have been poor.

Total loss of circulation, during the cementing operations, is an aspect to which solutions are not perfectly planned. Sections of casing lacked cement, and in this case the application of fine sand by gravity has been used to fill the annular spaces, since it was very difficult if not impossible to determine the top of the cement when using shots. It has been possible only once to use squeeze cementing, and besides when the casing is perforated, this part weakens when the well is flowing, and it could permit the escape of geothermal fluid or the invasion of other fluids that could damage seriously the well. The application of sand by gravity has given reasonable good results.

CONST. DATE	CONDUCTOR CSG.				SURFACE CSG.				INTERMEDIATE CSG.				PRODUCTION CSG.				SLOTTED LINER (PRODUCTION)			
	O.D. IN.	WT. LB/FT.	GRADE	JOINT	O.D. IN.	WT. LB/FT.	GRADE	JOINT	O.D. IN.	WT. LB/FT.	GRADE	JOINT	O.D. IN.	WT. LB/FT.	GRADE	JOINT	O.D. IN.	WT. LB/FT.	GRADE	JOINT
1964	22	65.24	B	WELD	16	65	H-40	R.T.	11 3/4	47	J-55	B.T.					7 5/8	26.4	N-80	B.T.
1966-1974					16	65	H-40	R.T.	11 3/4	47 60	J-55 K-55	B.T B.T.	7 5/8	26.4	K-55	B.T.				
1977-1978	22		CED-40	WELD	16	75	K-55	B.T.	11 3/4	65	K-55	B.T.	7 5/8	45.3	K-55	HYDRIL S.E.U.				
1978-1980					20	94	H-40	R.T.	13 3/8	61	K-55	B.T.	9 5/8	43.5	N-80	B.T.	7	29	N-80	HYDRIL S.E.U.
1980	30	98.93	B	WELD	20	106.5	J-55	R.T.	13 3/8	68.0	K-55	B.T.	9 5/8	47	C-75	HYDRIL S.E.U.	7	29	C-75	HYDRIL S.E.U.

Table title: CONSTRUCTIVE DATA OF WELLS 1964 TO 1980

TABLE I

STRATIGRAPHIC SECTION OF THE CERRO PRIETO GEOTHERMAL FIELD

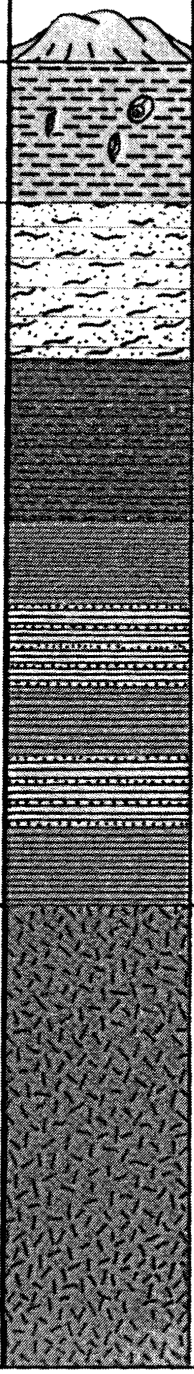
ERA	PERIOD	EPOCH	PETROLOGY	THICKNESS	LITHOLOGICAL DESCRIPTION
CENOZOIC	QUATERNARY	PLEISTOCENE		500 TO 2 300 m.	ANDESITE, CLAYS, FINE TO COARSE SAND QUARTZ, SILICA, FELDESPAR AND SCARCE GRAVEL DIABASE
	TERTIARY			1 TO 100 m.	CLAYSTONE SAND, SANDSTONE.
				100 m.	BROWN COLORED SHALE, INTERCALATED WITH SANDSTONE.
				GREATER THAN 2 200 m.	GRAY TO BLACK SHALE, ALTERNATIVE WITH SANDSTONES LIGHT GREYISH.
MESOZOIC	CRETACEOUS	SUPERIOR		?	GRANITE BIOTITE. 1980

TABLE 2

DRILLING MUD

TIPICAL MUD PROPERTIES

WEIGHT (Lb/GAL)	9.0
FUNNEL VISCOCITY (SEC/LT)	40
PLASTIC VISCOCITY (Cps.)	15
YIELD POINT (Lb/100 FT^2)	5
GELS (Lb/100 FT^2) o'& 10'	0-4
FILTRATE (ml 30 min)	6
CAKE THICKNESS (mm)	1
P. H.	9
SOLIDS (% by VOL.)	12
OIL (% by VOL.)	6
WATER (% by VOL.)	82
SAND (% by VOL.)	2 MAX.

SOLIDS AND TEMPERATURE CONTROL EQUIPMENT

TYPE	DEPTH INTERVAL
1 DUAL TANDEM TYPE, SOLID SEPARATOR WITH, DOUBLE MESH.	0.0 TO T.D.
2 SWECO SAND SEPARATORS WITH 8 HYDROCYCLONS	0.0 TO T.D.
1 COOLING TOWER TO HANDLE 2650 L/m.n.	T > 40 °C

DRILLING FLUID MATERIALS

BENTONITE

BARIUM SULPHATE

MODIFIED TANNING

SODIUM LIGNOSULFONATE

CAUSTCIZED LIGNITE

SODIUM HYDROXIDE

SODIUM CARBONATE

ADDITIVE CONTAINING A LOW MOLECULAR WEIGHT SYNTHETIC ORGANIC POLYELECTROLYTE.

LOST CIRCULATION MATERIALS

GRANULAR

FIBROUS

FLAKES

SODIUM SILICATE & CALCIUM CHLORIDE

CEMENT

C.G.C.P.

EXP.-6-XII-80

TABLE 3

PROBLEMS FREQUENTLY ENCOUNTERED DURING THE CEMENTING OF CASING

1.- PARTIAL OR TOTAL CIRCULATION LOSSES

2.- MECHANICAL FAILURES ON CEMENT COLLARS

3.- FAILURES ON CEMENT BASKETS

EFFECTS

1.- CEMENT CHANNELING

2.- TOTAL ABSENCE OF CEMENT

3.- INEFFECTIVE SQUEEZE CEMENTING JOBS

ACTUAL SOLUTIONS

1.- THE USE OF LIGHT CEMENTS ON HIGH PERMEABILITY ZONES AND, OR CEMENTING IN TWO STAGES.

2.- NEW TYPES OF CEMENT COLLARS AND CEMENT BASKETS.

TABLE 4

GEOTHERMAL WELLS
PARTICULAR ASPECTS

1._ CONSTRUCTIVE PROJECT
- a) TEMPERATURE
- b) CORROSION
- c) MASS VOLUME
- d) SPECIAL THREADS (CSG.)

2._ LOST CIRCULATION
- a) HIGH PERMEABILITY PRIMARY & SECONDARY.
- b) HYDROTHERMAL WASH
- c) LITHOLOGIC CONTACT ZONES

3._ ELECTRIC LOGS
- SPECIAL EQUIPMENT FOR HIGH TEMPERATURE.

4._ THERMAL LOGS
- KUSTER, AMERADA EQUIPMENT

5._ MODIFIED CEMENTS
- PERLITE, ACTIVATED POZZOLAN, SILICA

6._ CEMENTS
- ALL CASINGS, SPECIAL ACCESSORIES

7._ COMPLETION
- a) LITHOLOGICAL COLUMN
- b) MINERALOGICAL ANALYSIS
  - 1._ SEDIMENTARY ROCK
  - 2._ IGNEOUS ROCK
- c) MUD TEMPERATURE IN CIRCULATION
- d) KUSTER LOGS (TEMP.)
- e) ELECTRIC LOGS

8._ INITIAL PRODUCTION
- a) STIMULATION
- b) HEATING
- c) DEVELOPMENT
- d) EVALUATION

- RUSSELL JAMES
- SEPARATOR
- SILENCER

TABLE 5

CONCLUSIONS AND RECOMMENDATIONS

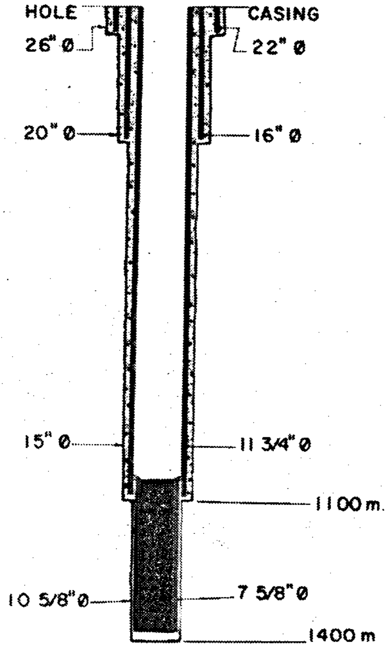
WE CONSIDER THAT RESOLUTIONS AND METHODS FOLLOWED TO SOLVE PROBLEMS ENCOUNTERED AT CERRO PRIETO, HAVE BEEN REASONABLY SATISFACTORY, BUT UNDOUBTEDLY THEY SHOULD BE IMPROVED, AND ABOVE ALL THE ASPECT OF CEMENTS AND THE CEMENTING EQUIPMENT. "FISHING" IS A LESS FREQUENT AND MOST DIFFICULT PROBLEM ESPECIALLY WHEN IT OCCURS IN THE HOT ZONES OF THE RESERVOIR.

DRILLING, MUDS, AND ABOVE ALL THE TIME EMPLOYED IN THE HOT DEEP ZONES, SHOULD BE IMPROVED TO REDUCE THE COST OF A WELL.

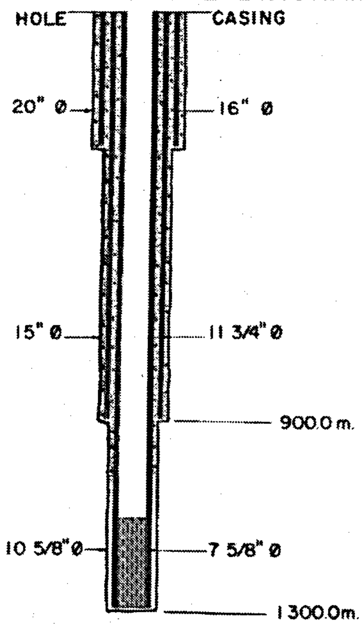
A VERY IMPORTANT ASPECT IS TO FIND BITS CAPABLE OF SUPPORTING HIGH TEMPERATURE GEOTHERMAL DRILLING, IN HIGHLY ABRASIVE SANDSTONE ZONES WITH HIGH TEMPERATURES AND GEOTHERMAL FLUID CONTENT. UP TO DATE RESULTS HAVE BEEN POOR, BITS LOSE MUCH OF THEIR STRENGTH WHEN THEY ARE OPERATED AT HIGHT TEMPERATURES, AND THEY FREQUENTLY CAUSE FISHING PROBLEMS AND SLOW PENETRATION RATES.

TABLE 6

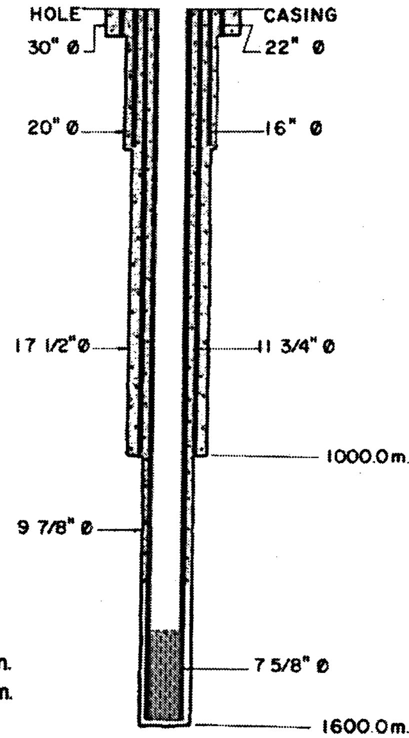
TUBULAR PROTOTYPE DIAGRAMS



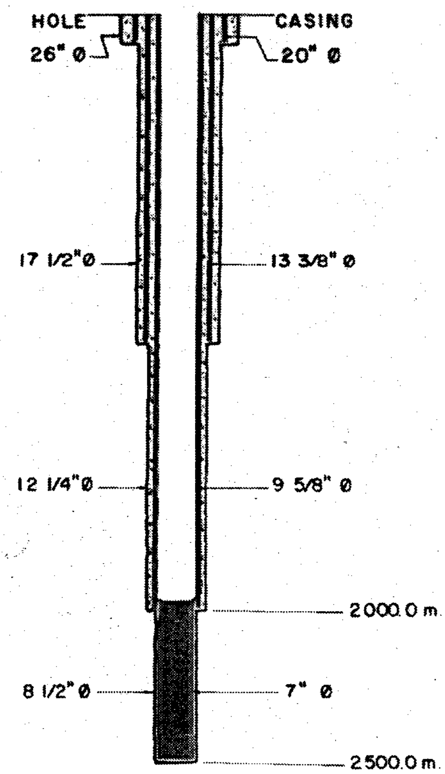
1964-4 WELLS 7 966 m



1966-1968 15 WELLS 20 825 m.
1972-1974 14 WELLS 18 838 m.



1977-1978 18 WELLS 35 400 m.



1978-1980 26 WELLS 62 450 m.

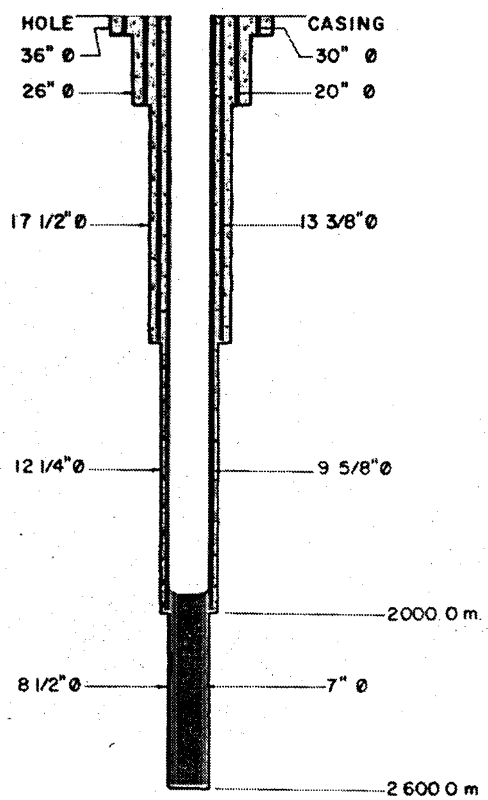


FIG. I

LOCATION OF THE MEXICALI VALLEY

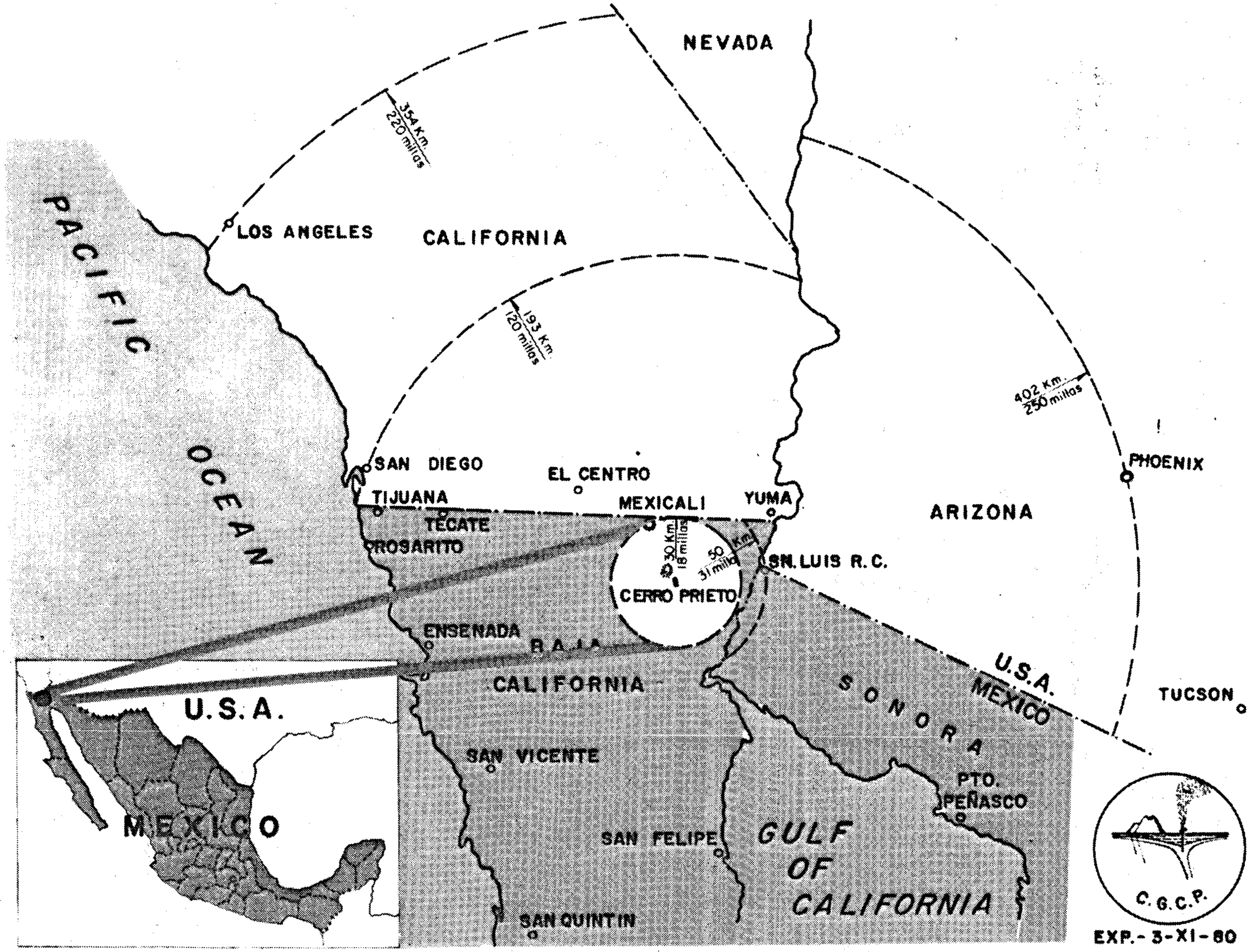
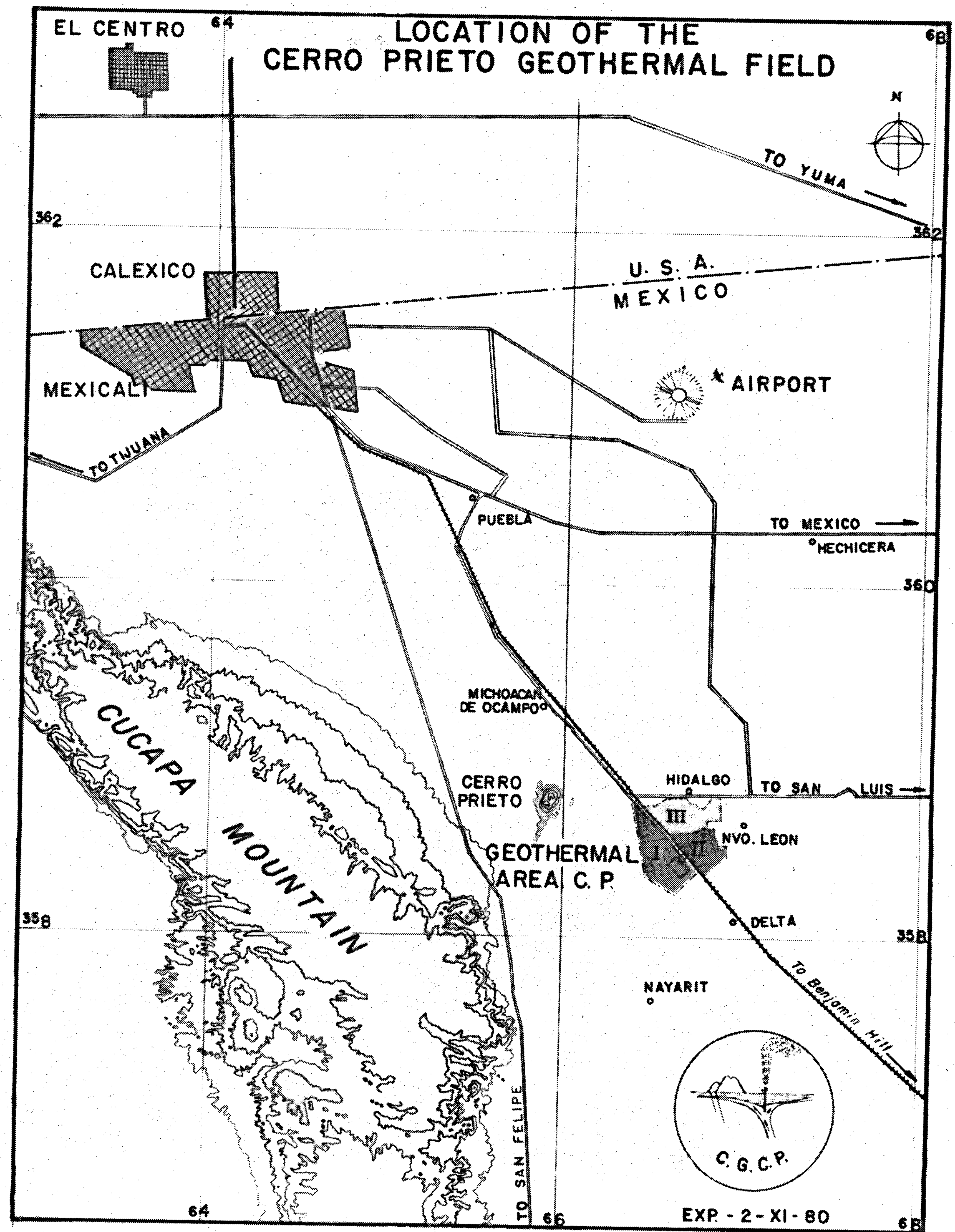


FIG. 2



LOCATION OF THE
CERRO PRIETO GEOTHERMAL FIELD
EL CENTRO
64
68
N
TO YUMA
362
CALEXICO
U. S. A.
MEXICO
MEXICALI
AIRPORT
TO TIJUANA
PUEBLA
TO MEXICO
HECHICERA
360
CUCAPA MOUNTAIN
MICHOACAN
DE OCAMPO
CERRO
PRIETO
HIDALGO
TO SAN LUIS
III
NVO. LEON
GEOTHERMAL
AREA C. P.
I
II
DELTA
358
NAYARIT
To Benjamin Hill
TO SAN FELIPE
C. G. C. P.
66
EXP. - 2 - XI - 80

FIG. 3

WELLS CONSTRUCTED

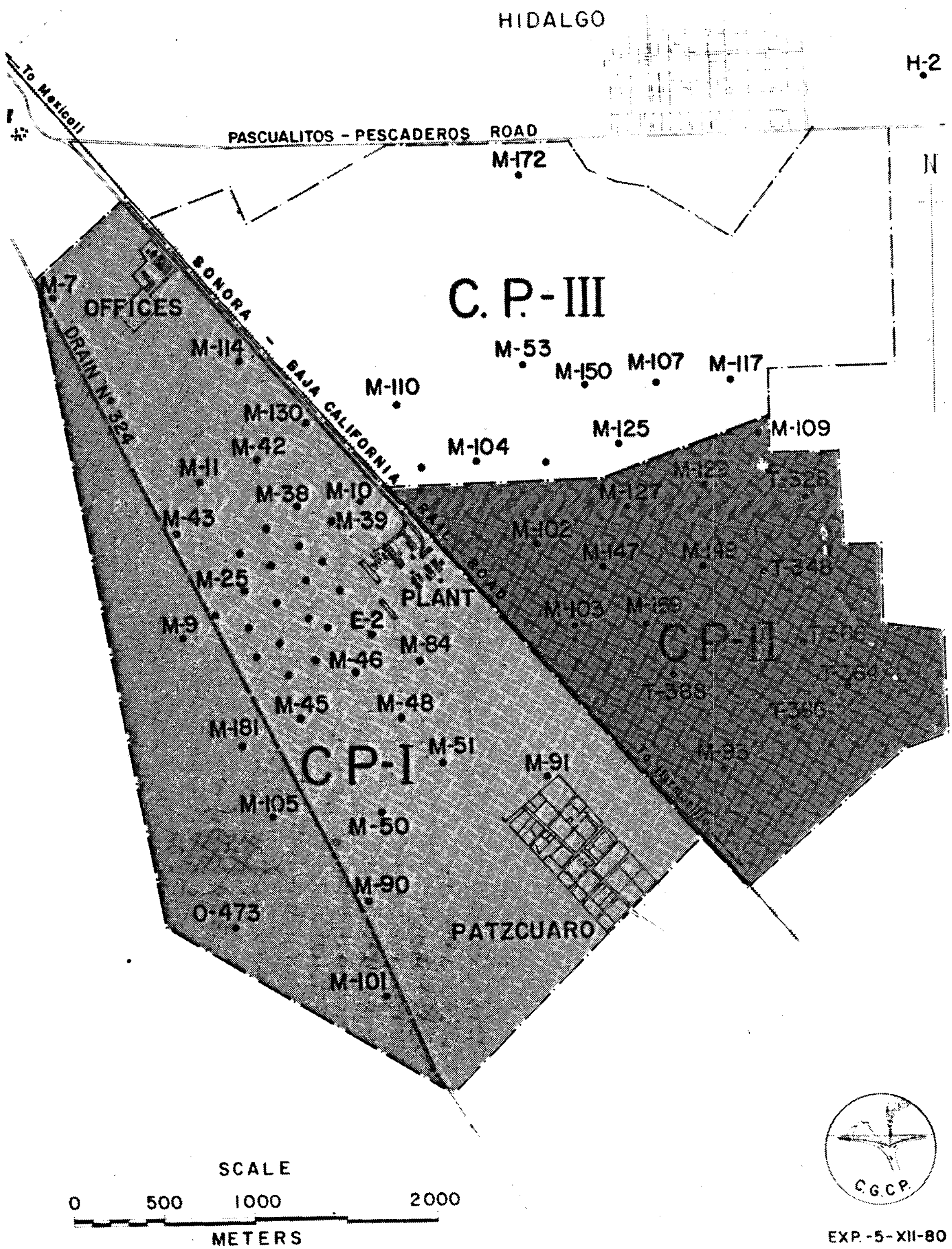


FIG. 4

PROGRAMMED WELLS

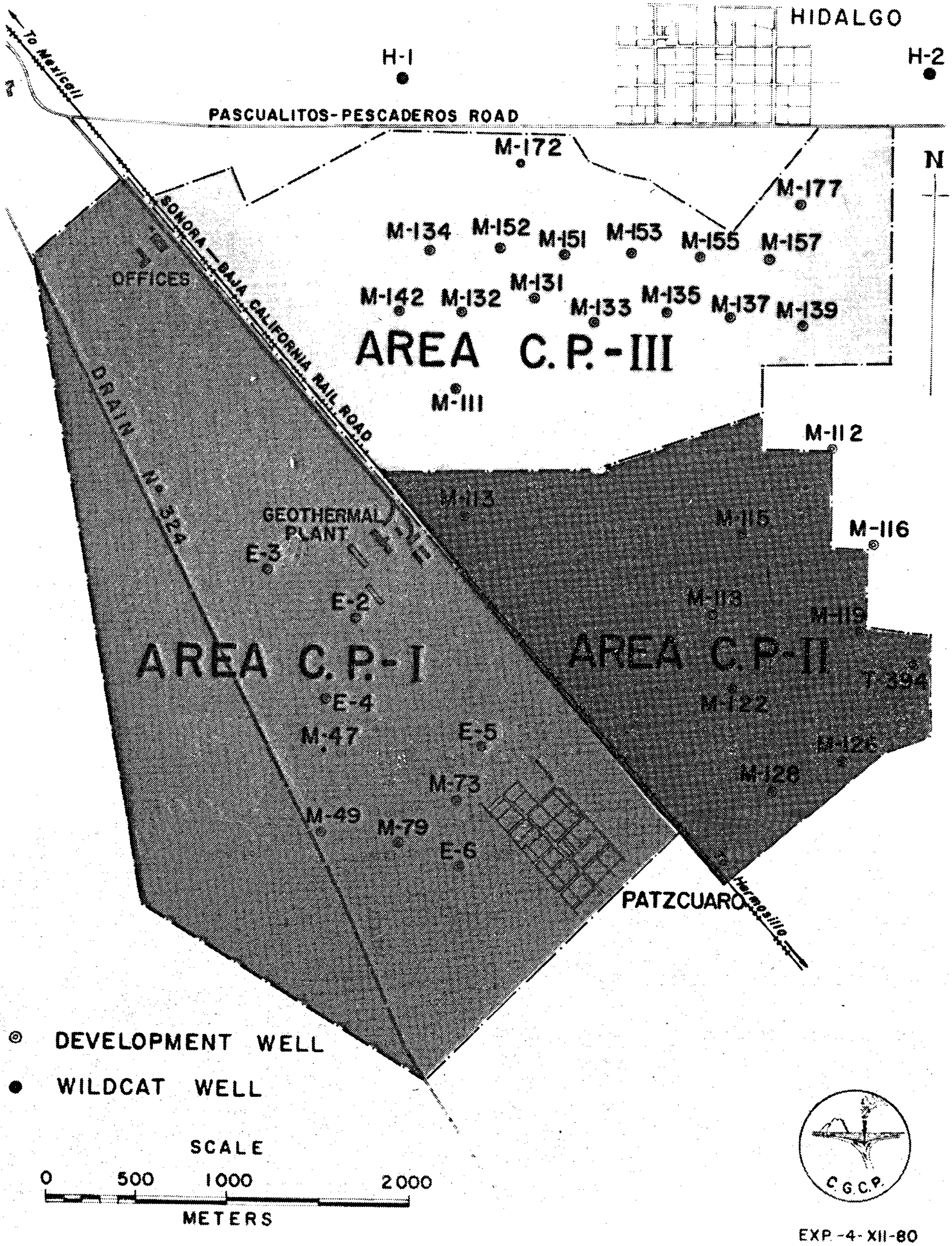


FIG. 5

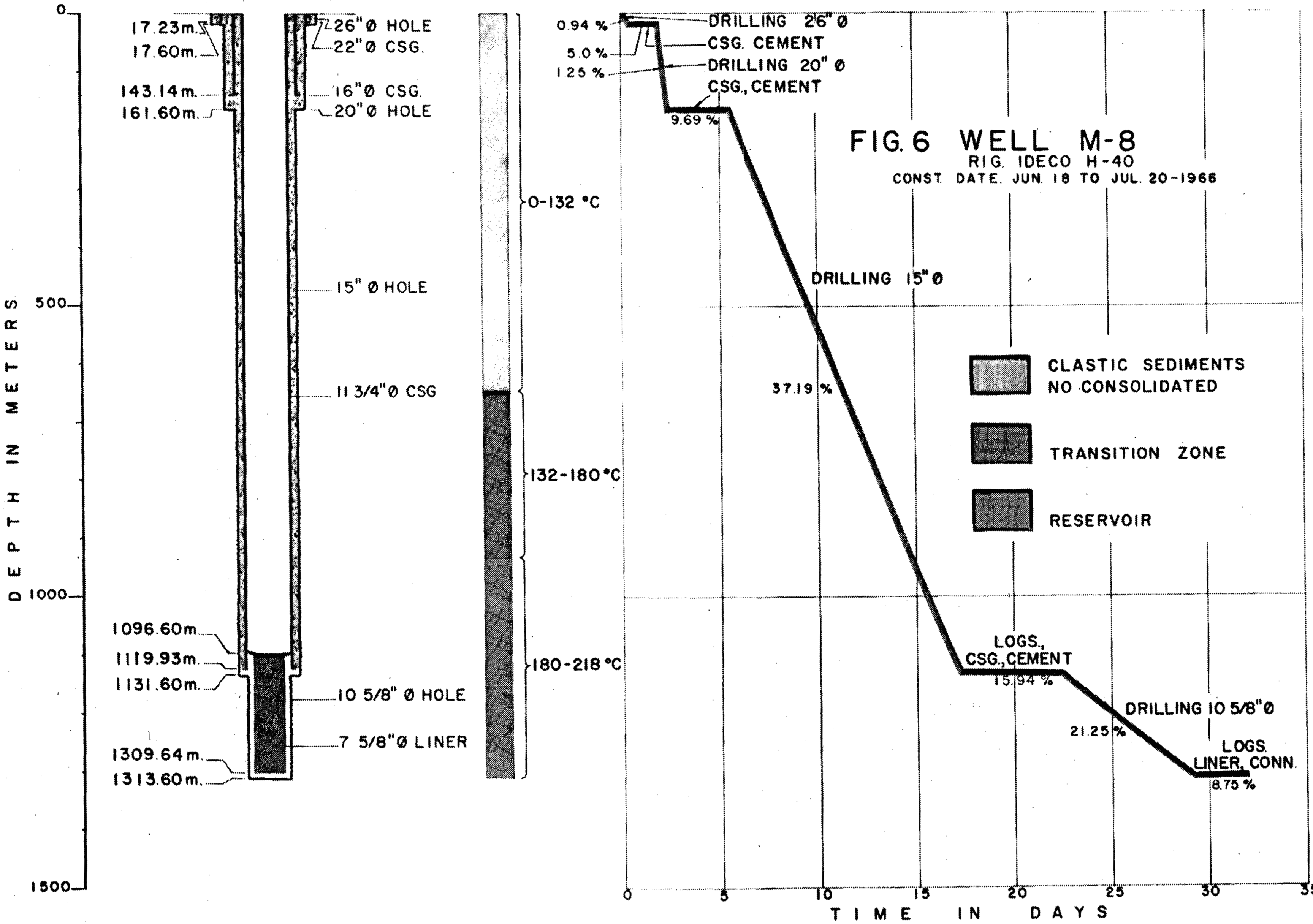


FIG. 6 WELL M-8
RIG. IDECO H-40
CONST. DATE. JUN. 18 TO JUL. 20-1966
DEPTH IN METERS
0
500
1000
1500
17.23m.
17.60m.
143.14m.
161.60m.
1096.60m.
1119.93m.
1131.60m.
1309.64m.
1313.60m.
26"Ø HOLE
22"Ø CSG.
16"Ø CSG.
20"Ø HOLE
15" Ø HOLE
11 3/4"Ø CSG
10 5/8" Ø HOLE
7 5/8"Ø LINER
0-132 °C
132-180 °C
180-218 °C
0.94 %
5.0 %
1.25 %
DRILLING 26"Ø
CSG. CEMENT
DRILLING 20" Ø
CSG., CEMENT
9.69 %
DRILLING 15"Ø
37.19 %
LOGS., CSG., CEMENT
15.94 %
DRILLING 10 5/8"Ø
21.25 %
LOGS. LINER, CONN.
8.75 %
CLASTIC SEDIMENTS NO CONSOLIDATED
TRANSITION ZONE
RESERVOIR
0
5
10
15
20
25
30
35
TIME IN DAYS

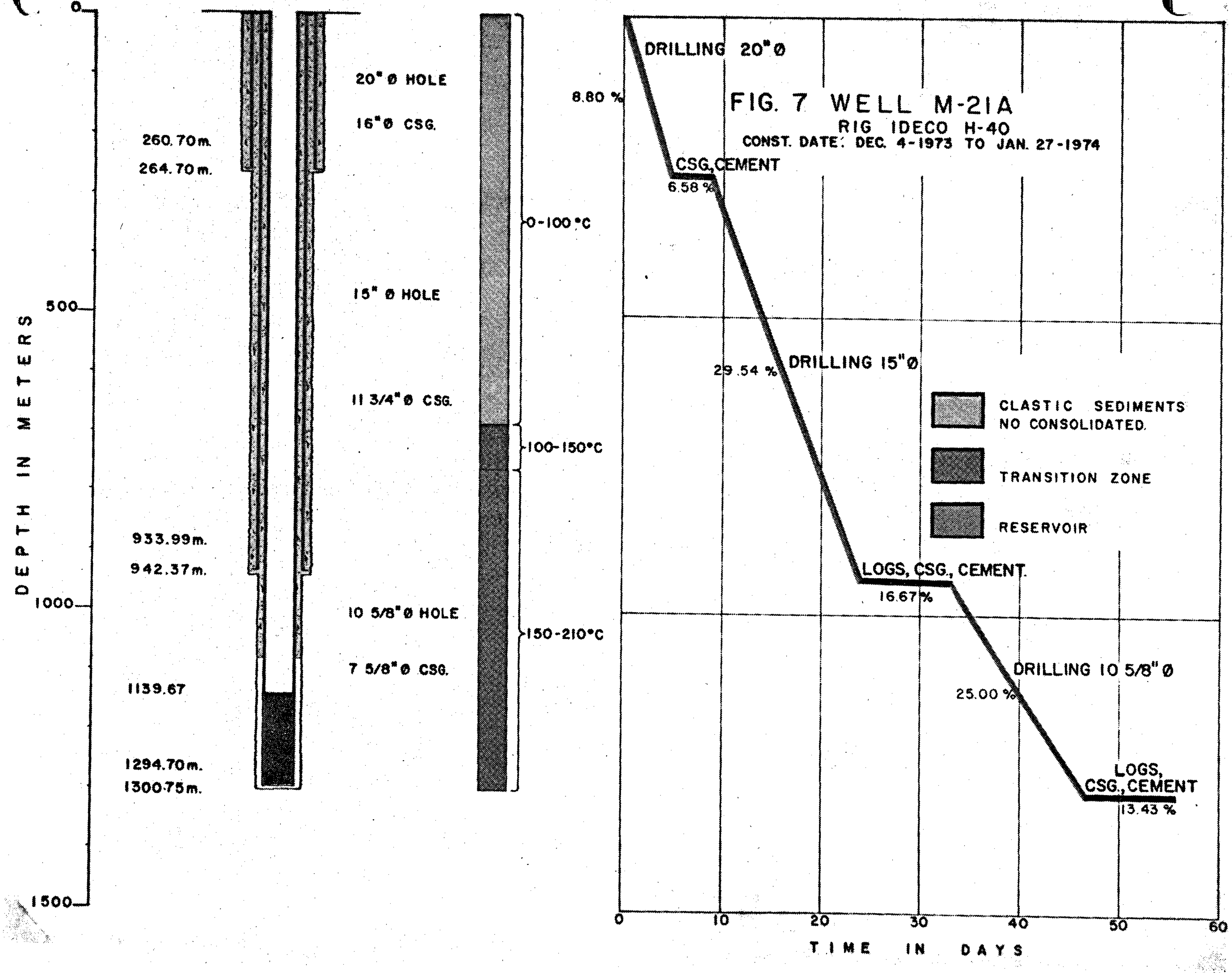


FIG. 7 WELL M-21A
RIG IDECO H-40
CONST. DATE: DEC. 4-1973 TO JAN. 27-1974
DEPTH IN METERS
0
500
1000
1500
260.70 m.
264.70 m.
933.99 m.
942.37 m.
1139.67
1294.70 m.
1300.75 m.
20" Ø HOLE
16" Ø CSG.
15" Ø HOLE
11 3/4" Ø CSG.
10 5/8" Ø HOLE
7 5/8" Ø CSG.
0-100 °C
100-150 °C
150-210 °C
DRILLING 20" Ø
8.80 %
CSG, CEMENT
6.58 %
29.54 %
DRILLING 15" Ø
LOGS, CSG., CEMENT.
16.67 %
DRILLING 10 5/8" Ø
25.00 %
LOGS, CSG., CEMENT
13.43 %
CLASTIC SEDIMENTS NO CONSOLIDATED.
TRANSITION ZONE
RESERVOIR
0
10
20
30
40
50
60
TIME IN DAYS

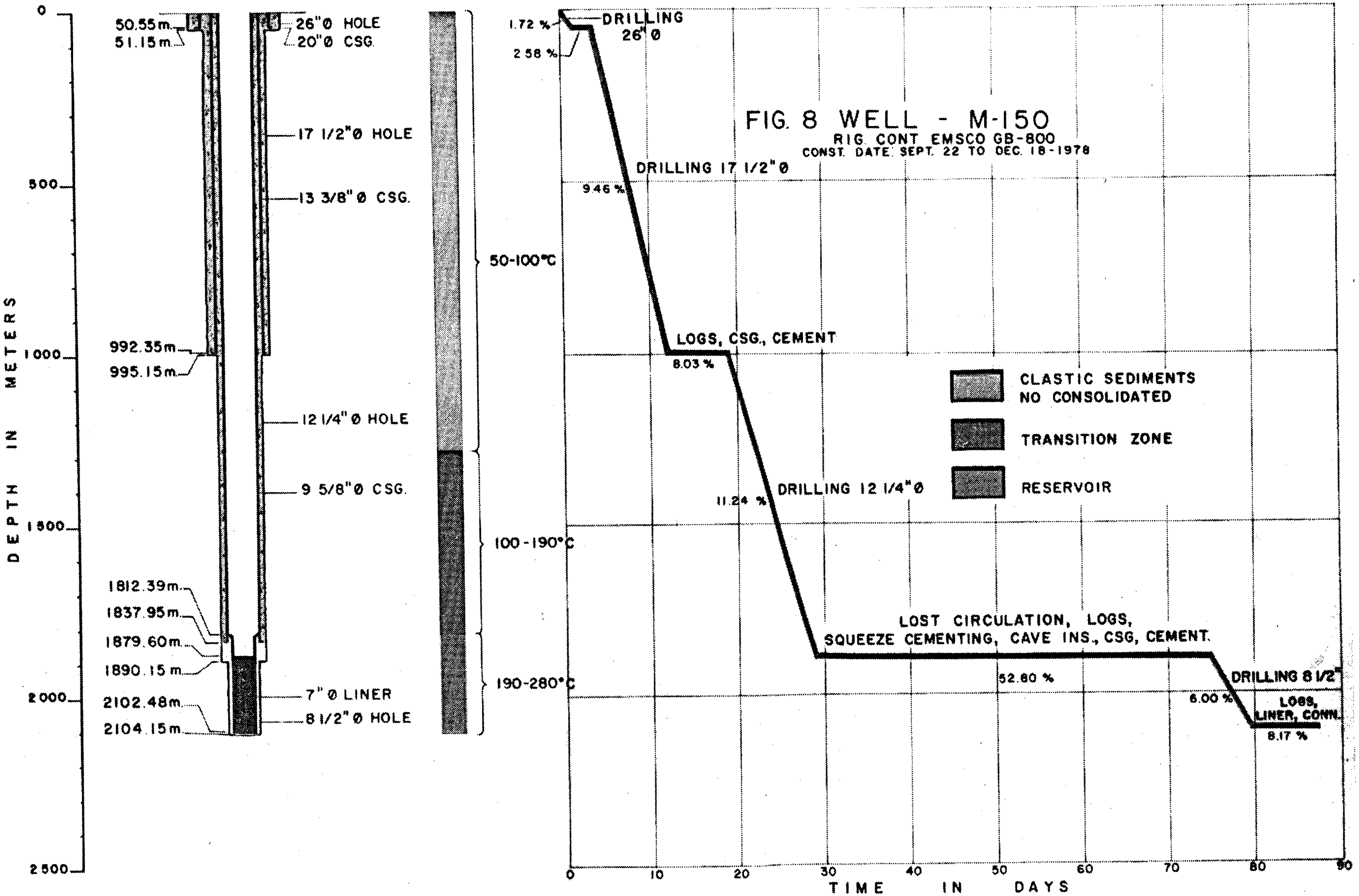


FIG. 8 WELL - M-150
RIG. CONT. EMSCO GB-800
CONST. DATE: SEPT. 22 TO DEC. 18-1978
DEPTH IN METERS
0
500
1000
1500
2000
2500
50.55 m.
51.15 m.
992.35 m.
995.15 m.
1812.39 m.
1837.95 m.
1879.60 m.
1890.15 m.
2102.48 m.
2104.15 m.
26"Ø HOLE
20"Ø CSG.
17 1/2"Ø HOLE
13 3/8"Ø CSG.
12 1/4"Ø HOLE
9 5/8"Ø CSG.
7"Ø LINER
8 1/2"Ø HOLE
50-100°C
100-190°C
190-280°C
1.72 %
2.58 %
DRILLING 26"Ø
DRILLING 17 1/2"Ø
9.46 %
LOGS, CSG., CEMENT
8.03 %
DRILLING 12 1/4"Ø
11.24 %
LOST CIRCULATION, LOGS,
SQUEEZE CEMENTING, CAVE INS., CSG, CEMENT.
52.80 %
DRILLING 8 1/2"
6.00 %
LOGS, LINER, CONN.
8.17 %
CLASTIC SEDIMENTS NO CONSOLIDATED
TRANSITION ZONE
RESERVOIR
0
10
20
30
40
50
60
70
80
90
TIME IN DAYS

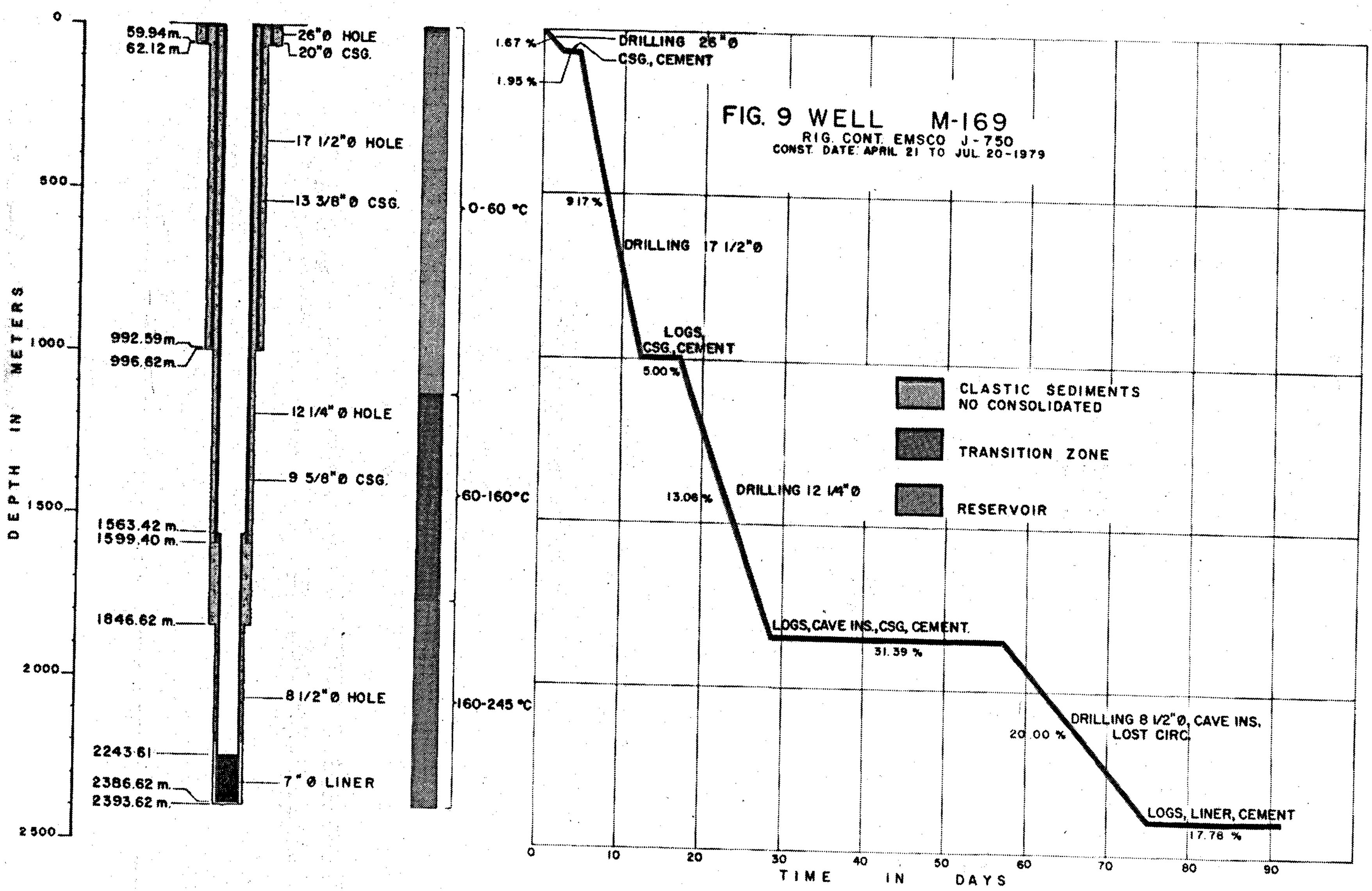


FIG. 9 WELL M-169
RIG. CONT. EMSCO J-750
CONST. DATE: APRIL 21 TO JUL. 20-1979
DEPTH IN METERS
0
500
1000
1500
2000
2500
59.94 m.
62.12 m.
26"Ø HOLE
20"Ø CSG.
17 1/2"Ø HOLE
13 3/8"Ø CSG.
992.59 m.
996.62 m.
12 1/4"Ø HOLE
9 5/8"Ø CSG.
1563.42 m.
1599.40 m.
1846.62 m.
8 1/2"Ø HOLE
2243.61
2386.62 m.
2393.62 m.
7"Ø LINER
0-60 °C
60-160 °C
160-245 °C
1.67 %
1.95 %
DRILLING 26"Ø
CSG., CEMENT
9.17 %
DRILLING 17 1/2"Ø
LOGS, CSG, CEMENT
5.00 %
13.06 %
DRILLING 12 1/4"Ø
LOGS, CAVE INS., CSG, CEMENT.
31.39 %
DRILLING 8 1/2"Ø, CAVE INS, LOST CIRC.
20.00 %
LOGS, LINER, CEMENT
17.78 %
CLASTIC SEDIMENTS NO CONSOLIDATED
TRANSITION ZONE
RESERVOIR
0
10
20
30
40
50
60
70
80
90
TIME IN DAYS

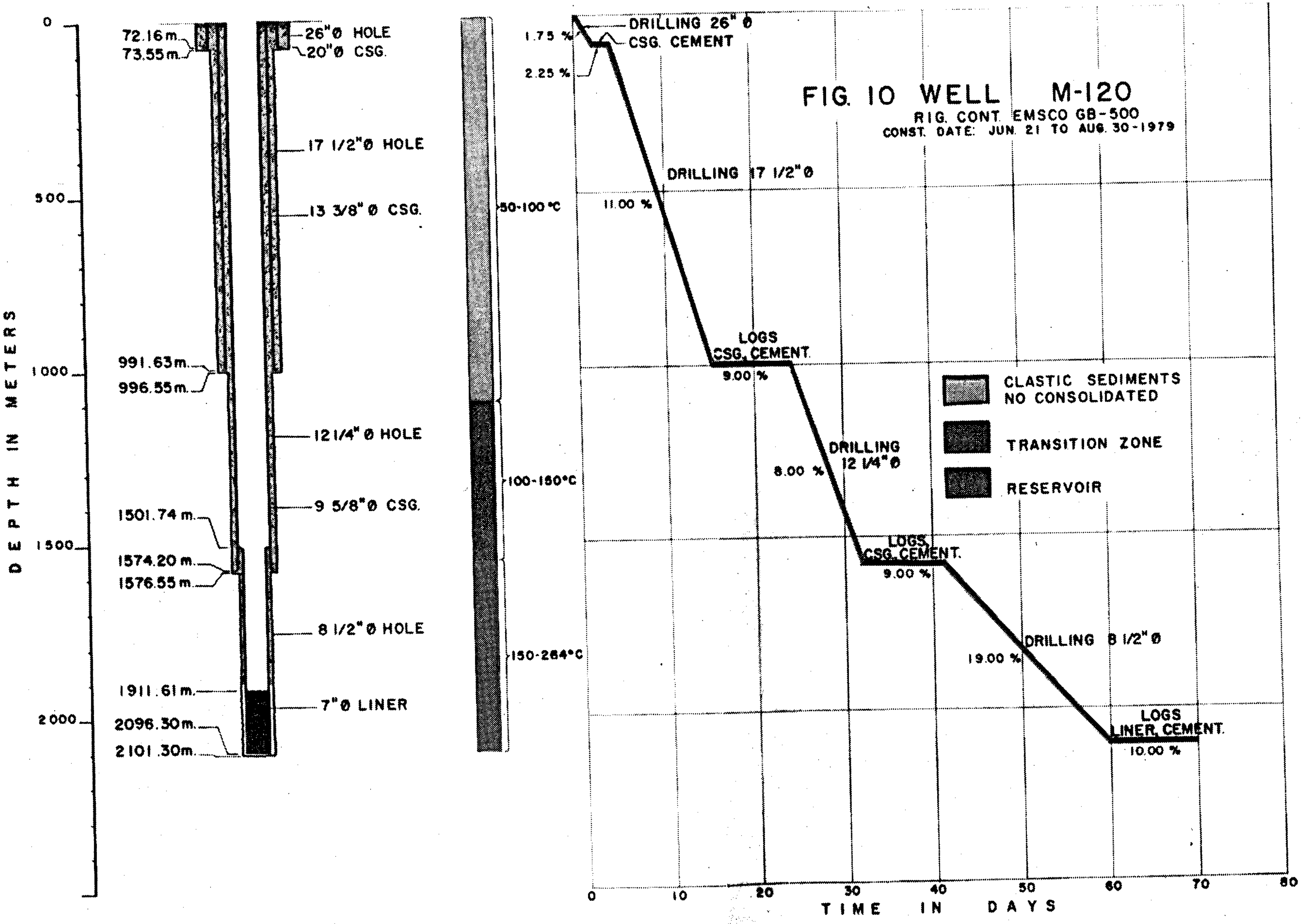


FIG. 10 WELL M-120
RIG. CONT. EMSCO GB-500
CONST. DATE: JUN. 21 TO AUG. 30-1979
DEPTH IN METERS
0
500
1000
1500
2000
72.16 m.
73.55 m.
991.63 m.
996.55 m.
1501.74 m.
1574.20 m.
1576.55 m.
1911.61 m.
2096.30 m.
2101.30 m.
26"Ø HOLE
20"Ø CSG.
17 1/2"Ø HOLE
13 3/8"Ø CSG.
12 1/4"Ø HOLE
9 5/8"Ø CSG.
8 1/2"Ø HOLE
7"Ø LINER
50-100 °C
100-150 °C
150-264 °C
DRILLING 26"Ø
CSG. CEMENT
1.75 %
2.25 %
DRILLING 17 1/2"Ø
11.00 %
LOGS
CSG. CEMENT
9.00 %
DRILLING
12 1/4"Ø
8.00 %
LOGS
CSG. CEMENT
9.00 %
DRILLING 8 1/2"Ø
19.00 %
LOGS
LINER, CEMENT
10.00 %
CLASTIC SEDIMENTS
NO CONSOLIDATED
TRANSITION ZONE
RESERVOIR
0
10
20
30
40
50
60
70
80
TIME IN DAYS